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THE MIDDLE COAL MEASURES OF THE WESTERN INTERIOR COAL FIELD.

THE most important coal field west of the Mississippi, so far as present development is concerned, is that which stretches from north central Iowa across portions of Missouri, Nebraska, Kansas, Arkansas, Indian Territory, and into Texas. In recent years there has been a good deal of geological work done within this field and some of the older conceptions of its stratigraphy are being changed. It is proposed to discuss here certain problems relating especially to the northern end of the field; that portion extending from central Iowa to southwestern Kansas.

The first extensive investigations of the geology of the Iowa-Missouri coal field were those of Owen¹ who traversed the main streams crossing the region and correctly outlined its limits. He determined the base of the Coal Measures and discovered many important facts with regard to structure and general geology, but made no attempts to build up a general section nor to divide the beds into minor formations. His successors, especially Swallow, Broadhead, and White, applied themselves to this task. Swallow, in an introductory statement regarding the Coal Measures of Missouri,² says that they appear to be separated into three divisions by two very important sandstones. These three divisions he calls "Upper," "Middle," and "Lower Coal Series." With the change "series" to "measures" this terminology was generally followed by writers on this region up to 1893 when Keyes, having previously noted the doubtful utility of the term Middle Coal Measures,³ suggested that the beds were better considered to form two formations which he named the Missouri and the Des Moines.⁴ In the succeeding reports of

¹ Geol. Surv. Wisconsin, Iowa, and Minnesota, 1852.

² Geol. Surv. Missouri, I and II, p. 78, 1855.

³ Bull. Geol. Soc. Amer., Vol. II, pp. 277-292, 1891.

Iowa Geol. Surv., Vol. I, p. 85, 1893.

the Iowa and Missouri surveys the beds formerly referred to the Middle Coal Measures have been considered to form a subordinate division of the Des Moines. In Kansas, Haworth has recognized a series of formations of which he correlates the lowermost, the Cherokee shales, with the Des Moines.¹ Above the Cherokee shales and below the Erie limestone, which is at least in a general way equivalent to the Bethany limestone, are placed the Oswego and Pawnee limestones, which with the interbedded shales, would seem to be the equivalents of the Middle Coal Measures of the older classification. Since the earlier work there has been less attempt to build up general sections of the Coal Measures of this field and the tendency has been rather to emphasize the diversity of the beds and the lack of continuity of the strata.

Non-persistence of individual strata is more or less characteristic of all shore formations. It is exceedingly difficult to conceive shore conditions under which beds could be deposited without this being true. When in addition it is remembered that there is excellent evidence that the particular shore line along which the lower Coal Measures of this field were laid down was unstable and subject to change through a considerable vertical range, it will be seen that the attempt to define subordinate formations in the Coal Measures cannot well be expected to yield satisfactory results. All the minor groups which are recognized may be expected to prove of local importance only.

The beds of the upper portion of the Coal Measures, however, beginning with the base of the Missourian formation, indicate that they were found under radically different conditions. Individual bands of limestone, ten feet and less in thickness, may be traced step by step for one hundred or two hundred miles.² Bands of black shale, the "slate" of the miners, a foot or less in thickness, seams of impure coal measured in inches only, and thin ledges of impure black limestone of the type elsewhere

¹ Univ. Geol. Surv. Kansas, Vol. I, p. 150, 1896.

² Bethany Limestone at Bethany, Mo., H. FOSTER BAIN; *Am. Jour. Sci.*, (4), Vol. V, pp. 433-439, 1898.

least constant in character, maintain themselves over areas of many miles. All of the beds, whether they be limestone made up of beach-rolled fragments, shale suggesting the infra-littoral zone of deposition, or the pure heavy limestone probably marking open sea deposition, are of such uniformity as to force the conclusion that only under conditions of widespread stability could they have been formed. In Kansas and the southern portion of the field there was an important recurrence of shore conditions later in Missourian time. In the portion of the field immediately under discussion, however, this later period of shore conditions is much less important and the uniformity which marks the opening of the Missourian, seems to have persisted throughout the period.

The change from the condition obtaining in the early Des Moines to those present when the Missourian began was a gradual one. During the former period there was no uniformity anywhere, and the field was broken up into a multitude of minor basins of deposition each the theater of an individual sequence of events, while during the latter the whole of southwestern Iowa, northwestern Missouri, eastern Kansas, and probably an even larger area, acted as a unit. The turbulent conditions of the earlier period became merged into the uniform conditions of the later one. Gradually larger and larger areas came to act together and local sequences came to have a wider and wider applicability. It is the beds of this intermediate period which were recognized as the Middle Coal Measures and in the absence of unconformity it will be seen that there is *a priori* reason to expect a series of beds intermediate in character and position between the typical Des Moines and the recognized base of the Missourian. All who have written on the subject have recognized that the Coal Measures mark a continuous sequence of deposition with only local breaks. Any divisions must be more or less arbitrarily established though they may be none the less useful.

The earliest complete section of the Middle Coal Measures published was that of Swallow.¹ A comparison of the plates

¹ Geol. Surv. Missouri, I and II, pp. 82-86, 1855.

given by him with the general section published by White¹ shows a great similarity in the character of the beds, and parts of his section even show a general similarity of sequence. The section given by White was based largely upon investigations carried on along the Raccoon River in central Iowa, a region recently restudied by the present Iowa survey. The section made out in the course of the present work is much the same as a portion of that earlier published. There are, however, certain changes of importance. The upper part as originally published² is essentially as given below, the original section numbers being retained.

	Feet
44. Arenaceous shale and sandstone, - - -	10
43. Bituminous shale, - - - - -	4
42. Lonsdale coal, - - - - -	2
41. Shales, light and blue, - - - - -	15
40. Limestone, - - - - -	5
39. Shales, light red, blue, arenaceous, - - -	30
38. Limestone, impure, dark blue, - - - - -	2
37. Bituminous shale and coal, - - - - -	3
36. Shales, yellow and blue, - - - - -	5
35. Sandstone, - - - - -	10
34. Shales arenaceous, yellow and blue, - - -	15
33. Marshall coal, - - - - -	1 ½
32. Shales, blue and yellow, - - - - -	8
31. Limestone, impure, fragmentary, bluish buff, -	2

These beds vary more or less in thickness, but maintain the same sequence over a considerable area.³ The Lonsdale coal is still worked at the type locality and lies about thirty feet below the base of the Bethany limestone. The heavy sandstone, No. 35, is well exposed and easily recognized. Below the section as given there is a sequence composed mainly of shales estimated to be about 150 feet thick. Below this in turn is a series almost identical with that just quoted, but in which

¹ Geol. of Iowa, Vol. I, pp. 272, 1870.

² WHITE, loc. cit.

³ Geol. Guthrie county, Iowa, Geol. Surv., VII, pp. 428-446, 1897; Geol. Madison county, *ibid.*, pp. 504-509; Geol. Dallas county, *ibid.*, VIII, pp. 78-82, 1898.

the coal seams are named Wheeler, Panora, and Lacona respectively. One of the results of the recent work has been to show that this presumed lower sequence is in fact a repetition of the upper portion, brought about by gentle folding.

In following down the South Raccoon River and many of its tributaries the beds already enumerated are easily recognized.¹ A portion of the section is exposed upon Middle Raccoon southwest of Linden, where it is seen to be essentially the same as originally given by St. John.² According to the interpretation of that author the beds found in passing both up and down the river from this point were lower. Below the section already quoted he placed a thickness of 145 feet of sandy and variegated shales, and below these a series including three seams of coal and with a sequence remarkably similar to that found above the shales.³ This hypothesis would require that the beds should rise between Panora and Linden enough not only to compensate for the fall of the stream but to throw high above the river strata deeply buried at the latter point. All dips in the region are slight and the one required here would be greater than any known to be present. Furthermore, recent studies show that the dip from Panora north is in exactly the opposite direction. It seems accordingly that the beds at Panora are to be correlated with the section already given rather than placed below it.

Traveling down the Middle Raccoon the beds rise to Redfield, at which point a thick, massive sandstone fifty feet thick is exposed below them. Below Redfield the sandstone declines and the same sequence as was seen at Linden may be made out.⁴ In the southeastern corner of the county the lower portion of the section previously quoted is present overlying a mass of variegated shales. These shales are seen in Polk county, east of Dallas, and only the upper part presents any evidence of regularity. They extend down to the base of the Coal Measures and contain the bulk of the workable coal. The portion

¹ Geol. Guthrie county, pp. 436-437.

⁴ Geol. Dallas county, pp. 64-67.

² See Geology of Guthrie county, p. 430.

³ See for comparison, Geol. Guthrie county, p. 429.

which is more or less regular in sequence does not correspond to the lower portion of the Middle Measures as originally described,¹ but shows very different succession.

The Des Moines beds, then, in the central portion of the state consist of a thick mass of shales and sandstones, showing no definite order of arrangement which may be recognized over any considerable area, covered by more regular sequence of which the upper portion may be recognized over a considerable area; but as one travels south two changes take place. (1) The upper member of the section, No. 44, thickness from barely thirty feet on the South Racoon to over seventy feet on Middle River near Winterset. (2) The various members of the section thin out and are replaced until in the southeastern portion of Madison county none of them can be made out. The section immediately below the Bethany limestone in the latter region is given below. It will be noticed that while none of the beds of the previous section can be recognized, the general character of the strata is the same.

	Feet	Inches
22. Shales, drab, argillaceous, with abundant <i>Derbya crassa</i> , <i>Chonetes</i> , probably <i>Chonetes parvus</i> Shum, at the top,	12	
21. Shales, red, argillaceous, - - - - -	3	
20. Limestone, fragmental, earthy, with bits of fossils, -		2
19. Shale, blue to green, argillaceous, grading into red below,	3	
18. Shales, blue to green, sandy, with nodular segregations of limestone, - - - - -	12	
17. Shales, blue, calcareous, - - - - -	12	
16. Limestone, compact, - - - - -		2
15. Limestone, fragmental, loose, with young <i>Chonetes meso-</i> <i>loba</i> , - - - - -		10
14. Limestone, fragmental, but firmly cemented, reddish color, with <i>Spirifer cameratus</i> and <i>Productus costatus</i> ,	1	
13. Shales, green, argillaceous, - - - - -	29	
12. Limestone, blue to black, in two ledges, with <i>Spirifer</i> <i>cameratus</i> , <i>Rhynchonella</i> and <i>Productus</i> , - - -	1	
11. Shale, carbonaceous, - - - - -	2	
10. Shale, clayey, drab, - - - - -	1	

¹ Geol. Polk county, Iowa Geol. Surv., Vol. VII, pp. 302-310, and Geol. Iowa (White), Vol. I, pp. 272-283.

	Feet	Inches
9. Shale, yellow, sandy, with marked horizontal bedding planes, - - - - -	4	
8. Shales, black to drab, carbonaceous, - - - - -		6
7. Limestone, nodular, sandy, with <i>Productus cora</i> , <i>Chonetes mesoloba</i> and <i>Athyris subtilita</i> , - - - - -	1	4
6. Shale, gray, sandy, - - - - -	3	
5. Limestone, similar to number 7, - - - - -		10
4. Shale, clayey, drab to blue, - - - - -		10
3. Shale, carbonaceous, - - - - -	1	
2. Limestone, thin bedded, leaf-like in texture, with <i>Productus muricatus</i> , <i>Chonetes mesoloba</i> , <i>Derbya crassa</i> and <i>Productus costatus</i> , - - - - -		3
1. Clay, green, - - - - -	3	

South from here in Clark and Lucas counties the work has not yet been carried on in sufficient detail to allow a general section to be made out. It is, however, known that there are in the region strata of the same general type as those found in Madison, Dallas and Guthrie counties, though probably detailed correlation will be impossible.

Along the southern border of the state the Des Moines beds outcrop from the Mississippi River west to Decatur county, where they become buried beneath the Bethany. As far west as the Chariton River the beds may be referred unhesitatingly to the lower division, corresponding, as noted above, with the Cherokee shales. Their character is shown in exposures and mine sections along the Chicago, Milwaukee and St. Paul Railway from Ottumwa southwest.¹ Above these is a formation, including several limestone beds and one widely worked seam of coal, which has been called the Appanoose formation.² In general character these strata correspond to those seen farther north at the same horizon. A generalized section is given below:

	Feet	Inches
17. Limestone, gray, subcrystalline, seen in the railway cut near Anchor No. 1 mine at Centerville, and known among the miners as the "floating rock," - - - - -	2-4	
16. Shale, argillaceous, color variable, - - - - -	12-30	

¹ Iowa Geol. Surv., Vol. V, Pl. XIV.

² Iowa Geol. Surv., Vol. V, pp. 378-394.

	Feet	Inches
15. Limestone, heavy ledges, exposed along Manson branch and Cooper Creek at Centerville, as well as at numerous other points in the county, the "fifty-foot limestone,"	4-10	
14. Shale, argillaceous, blue and red in color, - - -	14	
13. Shale, arenaceous, frequently forming a well defined sandstone, as in boring No. 3 (No. 13), and the Rock Valley shaft, - - - - -	8	
12. Shale, argillaceous, blue to gray, - - - - -	10	
11. Limestone, somewhat variable in thickness; exposed along the C., M. & St. P. railway, between Mystic and Brazil, known as the "seventeen-foot limestone" or "little rock," - - - - -	1-3	
10. Shale, sometimes gray, frequently bituminous and pyritiferous, - - - - -	7	
9. Limestone, sometimes gray, and coarsely sub-crystalline as at the Lodwick mine, Mystic; sometimes fine-grained, bituminous, and grading into the shales above and below, as at the Thistle mine, Cincinnati; known as the "cap rock," - - - - -	2-4	
8. Shale, usually bituminous, and known as "slate;" occasionally in part soft and clay-like, then known as clod; at times heavy and homogeneous non-fissile, in which form it is known as "black bat," - - - - -	1-3	
7. Coal, upper bench, usually, - - - - -	1	8-10
6. Clay parting "mud band," - - - - -		2- 3
5. Coal, lower bench, usually, - - - - -		8-10
4. Clay parting the "dutchman," - - - - -		½
3. Coal, frequently not so pure, - - - - -		2- 3
2. Fire clay, - - - - -	1-6	
1. Limestone, "bottom rock," well exposed along Walnut Creek at Mystic, - - - - -	3	6

This section was first made out in 1893 and published in the following year.¹ It was not, however, until 1896 that the name Appanoose was applied to the beds. At this time² they were defined as a subdivision of the Des Moines formation and sections were given illustrating their relations to the underlying and overlying strata. Above the Appanoose formation there is

¹ Amer. Geol., XIII, 407-411; Proc. Iowa Acad. Sci., Vol. I, Pt. IV, 33-36; Iowa Geol. Surv., II, 407.

² Iowa Geol. Surv., V, 378-394.

at one point an unconformable conglomerate.¹ Little is known of this formation, but it seems to be essentially local. The beds between the upper member of the Appanoose, the "floating rock" of the miners and the lowermost member of the Bethany as shown in Decatur county are but infrequently exposed and little is known concerning them. If one may judge from the topography and the infrequent exposures, the intervening beds are shales, predominantly sandy.

The three Iowa sections from the St. Louis limestone to the Bethany may be summarized as below:

NORTHERN SECTION: Jasper, Polk, Dallas, and Guthrie counties	MIDDLE SECTION: Monroe, Lucas, and Clark counties	SOUTHERN SECTION: Van Buren, Davis, Appanoose, Wayne, and Decatur counties
Feet	Feet	Feet
3. Sandy shales not to be separated from the underlying formation, 30	3. Beds covered; probably sandy shales, 50-70	3. Sandy shales, only partially exposed, 75 (Chariton Conglomerate, local.)
2. Shales, limestone, three coal beds, upper portion of old Middle Coal Measures, - 100	2. Equivalents, section not yet made out, 100	2. Appanoose beds, - 100
1. Shales, heavy sandstone and non-persistent but thicker coal beds, - 400-500	1. Equivalent and similar beds, - 200-400	1. Equivalent and similar beds, - 400-600

The lowermost division is clearly the equivalent of the Cherokee shales of Kansas. The variation in its thickness is due to the erosion unconformity between it and the underlying St. Louis limestone. The middle division exhibits the same general characteristics of thin persistent limestone and coal

¹ Loc. cit., pp. 394-398.

beds throughout the state but varies in detail so much that it is impossible to correlate the individual beds of the north, middle and south sections. The uppermost beds represent a recurrence of the type of sedimentation shown by the lower member and present a notable thickening to the south. Indeed this member is practically absent at the northern end of the area so that the Iowan field includes apparently only the northern half of an immense lense of sandy material, intercalated between the limestones of the Bethany and the Appanoose formations.

As has been pointed out by Keyes¹ there is a close correspondence between the sections made out in Iowa, Missouri, and Kansas. These may be summarized as below.

	Iowa	Missouri	Kansas
3.	No name	Pleasanton	Pleasanton
2.	Appanoose	Henrietta	Pawnee Oswego
1.	Cherokee	Cherokee	Cherokee

The Middle Coal Measures as originally defined included the two upper divisions noted here. Swallow² recognized along the Missouri and at the top of his section some thirty feet of sandy shales. White and St. John found about the same thickness along the Raccoon River. Between these two points it is now known that the sandy member attains a considerable thickness and becomes sufficiently distinct to perhaps warrant giving it a separate designation. For this division Haworth's term Pleasanton³ seems to have precedence if the beds are to be considered as distinct from the next lower formation.

The middle member of the above table includes the major

¹ Proc. Iowa Acad. Sci., Vol. IV, pp. 22-25, 1897.

² Op. cit., pp. 82-83.

³ Kan. Univ. Quart., Vol. II, p. 274, 1895.

portion of the old Middle Coal Measures. As now defined, this median member forms a single well-defined formation, with certain uniform characteristics, and may be well recognized as a distinct unit. Toward the north limestones are thinner and more numerous, while to the south they come together and thicken, until in Kansas they form two well marked beds to which Haworth has given the names Oswego and Pawnee. The Henrietta limestone of Marbut¹ in southwestern Missouri seems to include these two limestones with an intervening shale bed. The whole forms a well defined escarpment which Marbut has traced across the southwestern portion of that state. No detailed section of the Henrietta formation has yet been published, so that the correlation of its individual beds cannot yet be made. In north central Missouri the formation seems to resemble more closely the beds found in southern Iowa, since the Mystic coal is widely recognized in Putnam, Schuyler, and Adair counties.² The whole series of sections would seem to indicate a gradual change of character, from the near shore beds of the Raccoon River section to the off shore beds of Kansas. This change is very gradual as the series of sections is taken parallel to the strike.

For this median member of the Des Moines series no good term has yet been proposed. The designations used in Kansas refer to individual parts of the formation. The name Henrietta and Appanose have been applied to distinctive phases of the formation. No general term has yet been used for the Raccoon River beds. If it is thought best to apply to the whole formation one of the names already in use, it would seem that Appanose would have precedence as being first clearly defined and located. There are, however, objections to this since the Appanose formation as now defined is coextensive with an important coal bed and hence has a definite economic significance. Henrietta has been used in the general sense here suggested,³

¹ Missouri Geol. Surv., Vol. X, p. 44, 1896.

² Proc. Iowa Acad. Sci., Vol. I, Pt. IV, p. 36, 1894.

³ Keyes, Proc. Iowa Acad. Sci., IV, 23; and Eng. Mining Jour., Feb. 26, 1898, p. 254.

but if this usage is to be adopted it would seem desirable that the formation be properly defined and some general section of it, as typically exposed, be given. Since, however, Henrietta was first applied to a distinctive phase of the formation, that displayed in southwestern Missouri, it will probably be found better in the end to adopt a general term for the whole region, retaining the terms now in use, Pawnee, Oswego, Henrietta, Appanoose, and Raccoon River beds, for local use. This is the more advisable, since, while the beds show certain general characters common to all and are probably of essentially contemporaneous origin, they really contain the record of deposition in four and perhaps more essentially distinct minor geological provinces.

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